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Evaluation of part consistency with photopolymer inserts in different injection moulding process parameters

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Abstract

Using additive manufacturing (AM) processes for direct fabrication of complex three-dimensional objects in a fewer time in comparison to the subtractive method is the advancement of this technology. This study connecting the AM with injection moulding (IM) process. AM inserts are directly manufactured by photopolymer material and used in IM process. Different combinations of IM parameters are used in order to find out the influence of various settings on the fabrication of the parts with soft inserts. The effects of injection moulding parameters are investigated by the use of a design of experiment (DOE) and optical metrology. DOE analysis concludes that the IM speed and cooling time are significant factors, for the geometry of the features. The height of bricks and knobs are also measured on the IM parts for assessment of different batches before any cracks appear on the inserts.

Experimental procedure

Additively Manufactured Insert

Digital Light Processing (DLP) machine was used for fabrication of insert. DLP is known for high precision elements and temperature resistant materials. The material used in this project is a brand new prototype material and no data sheet, material property or chemical composition is available due to confidentiality agreements. The insert design selected from previous study [4] with different micro features. Figure 1 shows the IM part and AM insert geometry of the insert.

Injection Moulding (IM) Experimental Procedure

The IM tests were carried out on an Arburg (370A 600-70), 60 tonne moulding machine. Acrylonitrile butadiene styrene (ABS) is chosen. The IM is carried out with standard settings for ABS and varying parameters for injection temperature, injection speed, mould temperature and cooling time. The remaining parameters are kept constant at 200 bar packing pressure and 4 s packing time. Attention was used to not raise the packing pressure too much, which could damage the rather fragile polymer inserts. A two-level half factorial design of experiments (DOE) with 4 factors was carried out to assess the effect of IM parameters on the lifetime of AM inserts. The tested IM parameters are listed in Table 1. The initial 5 moulded parts are collected in order to follow the changes during the lifetime of the insert.

Measurements

Olympus Lext OLS 4100 laser scanning digital microscope was used for the IM part measurements. Figure 2 shows the measured selected areas in red. Heights of both the heart and the brick cavities are estimated by measuring from the mould surface to the bottom of the cavities. The bricks are measured according to, two heights, both from the mould insert surface to mid plane of the brick and to the knob surface. Diameters of the brick knobs are estimated as an important dimensional feature that may be affected during moulding hence the top-right and bottom-left are chosen as reference area.

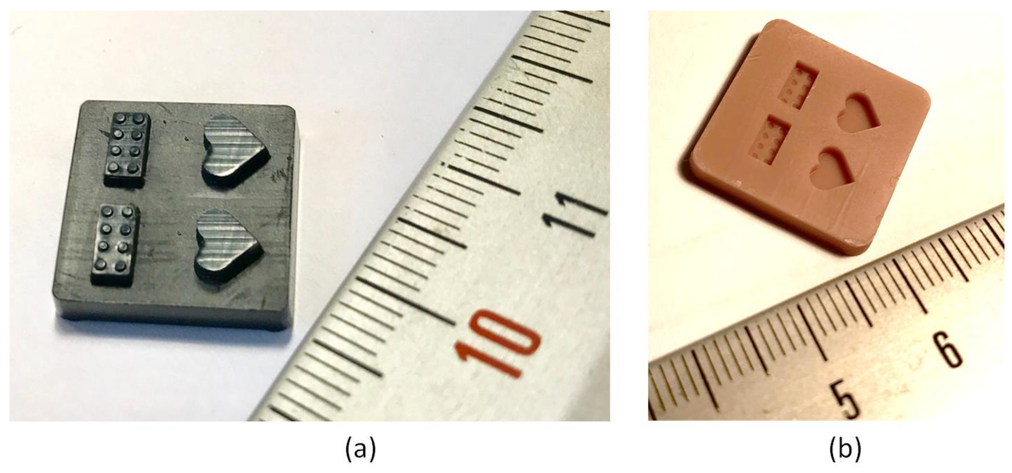

Fig. 1 (a) IM part (b) AM insert

TABLE 1 IM experimental factors and their levels

Factors	Low	High
Melt temperature	220 °C	260 °C
Injection speed	40 mm/s	80 mm/s
Mould temperature	25 °C	50 °C
Cooling time	0 s	5 s

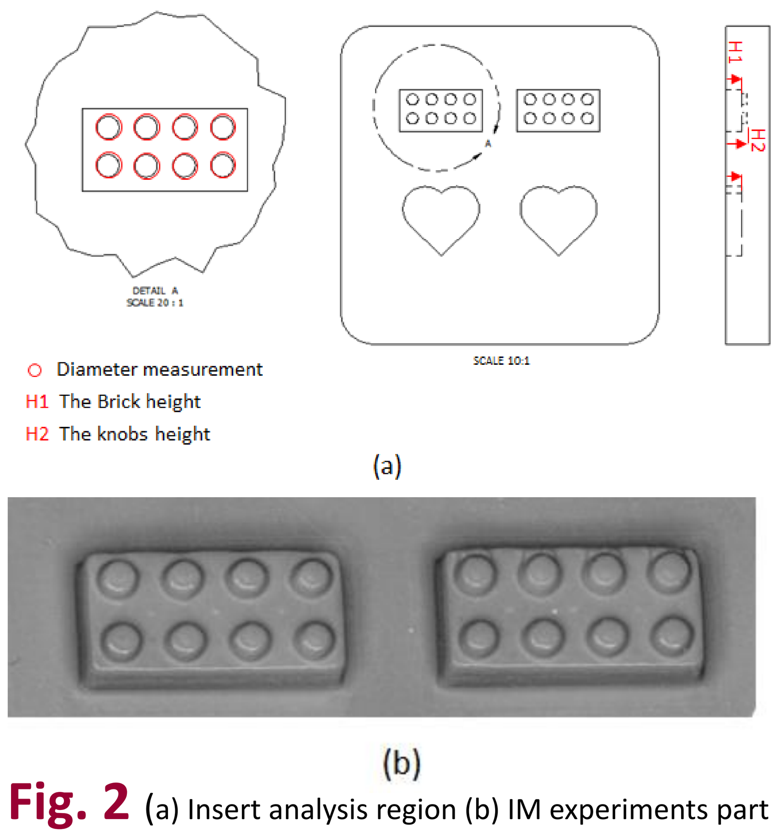

Fig. 2 (a) Insert analysis region (b) IM experiments part measurement area

Results

Figure 3 shows main effects plot for the combination of parameters for 8 tests. The influence of cooling time, IM speed, melt and mould temperatures were analyzed. The most influential factors were noticed as IM speed and cooling time. Therefore in a lower speed, 40 mm/s and more cooling time 5 s the diameter of the knobs were more uniform. This could be due to the small dimension of the features 800 µm that need more cooling time and lower speed to fill the shape properly during the IM process. However, the melt and mould temperature were not an influential factor to affect the diameter of the features.

The height of bricks and knobs are presented in Figure 4. The blue bar chart shows the bricks height and the line graph presents the height of knobs. IM parameters also affected the height of features. In batch A and D with 5 s cooling time, the highest features were observed with minimum standard deviation. The following measurement and analysis carried out on the IM parts before the crack appeared in the photopolymer inserts.

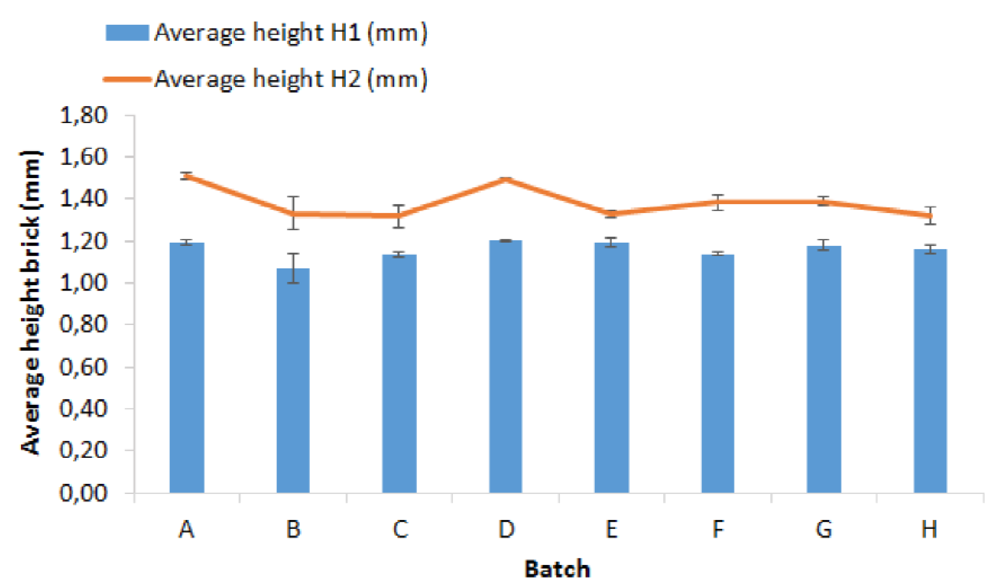

Fig. 4 The average height of the bricks and knobs

Conclusion

This project aimed at evaluating the IM parts in different parameters with AM inserts. The main focus is on investigating which IM factor have the main effects on the parts accuracy. The influences of four main IM parameters were investigated. From the DOE analysis, it was possible to conclude that the IM speed and cooling time were significant factors, affect the diameters of the brick knobs. Besides, the height measurements also revealed the importance of factors in different batches. The higher cooling time 5 s influence the height of the features. The tool life of the insert was also evaluated for the number of shots before the first crack appeared to affect the IM parts. In the future study, the tool life and the crack propagation of the photopolymer inserts will be investigated.

Acknowledgment

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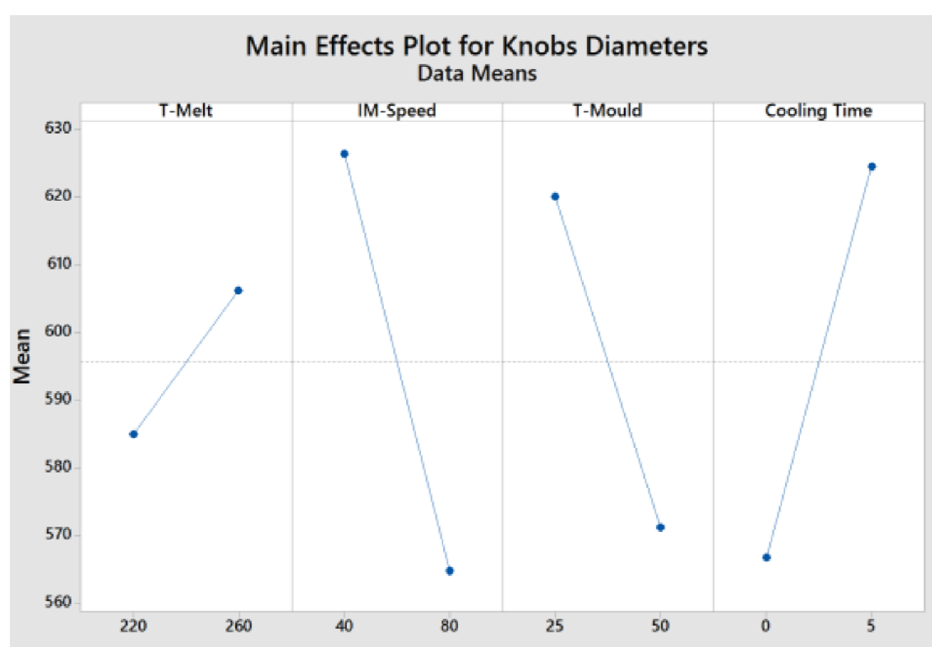

Fig. 3 *The Main effect plot for knobs diameters*